

Title: AN IMPROVED IMPELLER BLADE

Inventor(s): Bradbury, et al.— Express Mail Label No. EV 3200451689 US
Schulte Roth & Zabel, LLP – Todd Sicklinger, Esq.
Atty. Ref.: 861975/0270

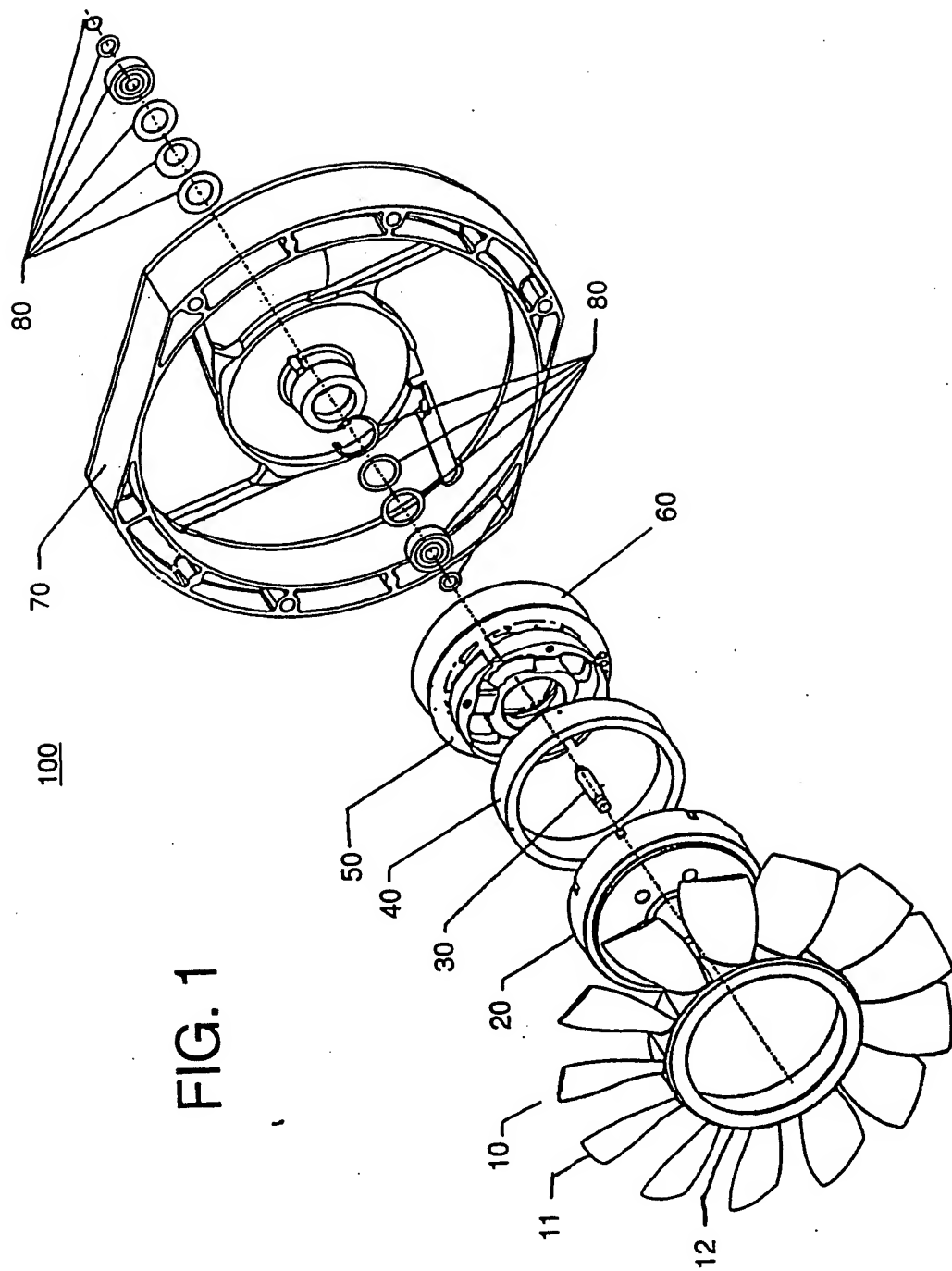


FIG. 1

100

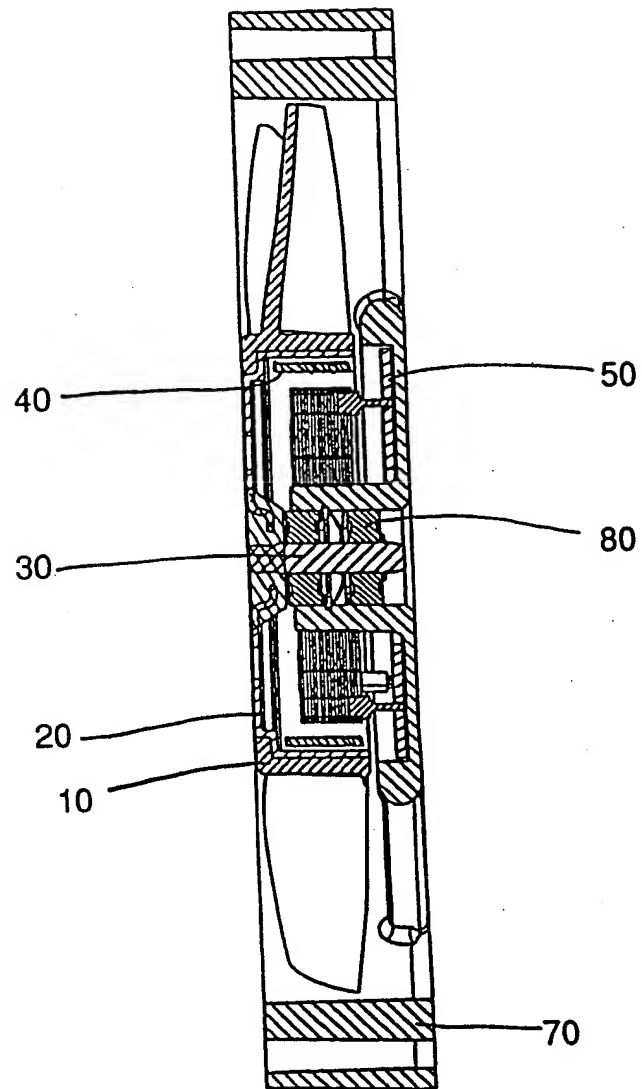


FIG. 2

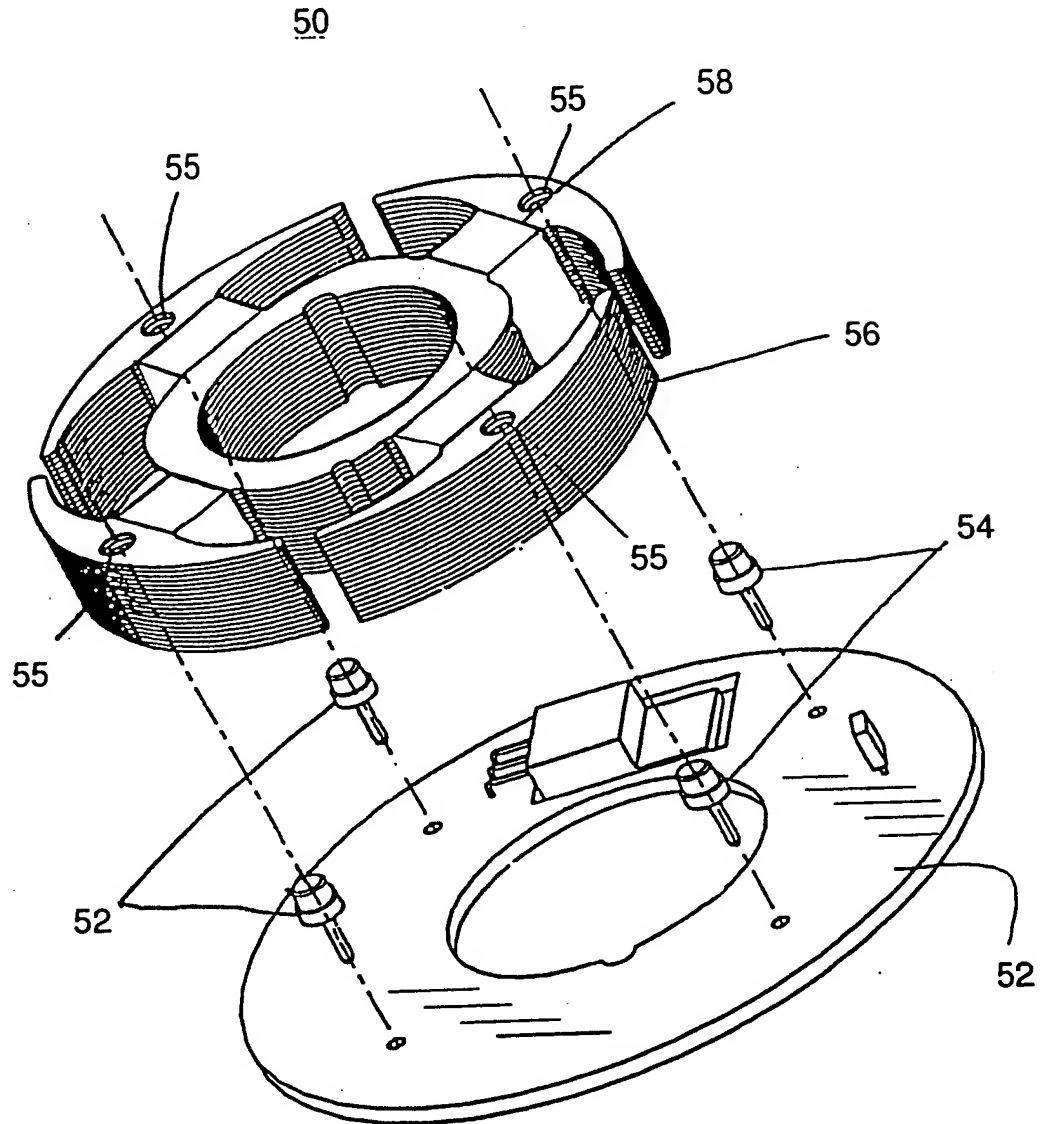


FIG. 3

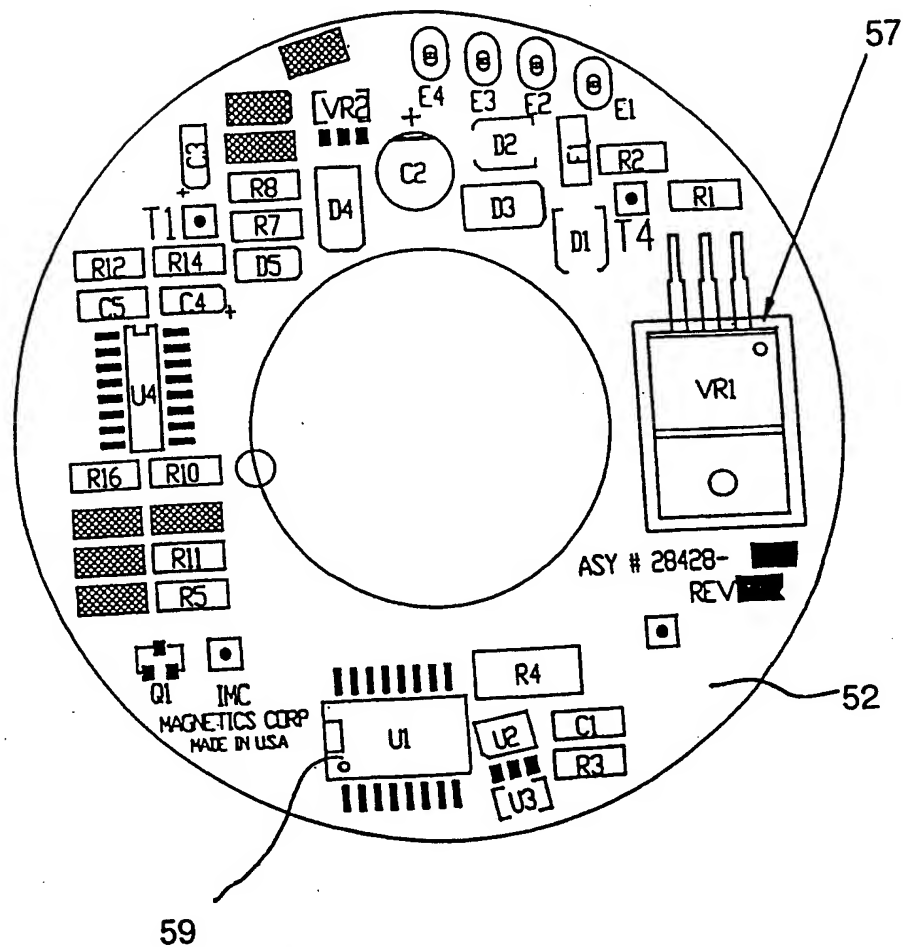


FIG.4

FIG. 5

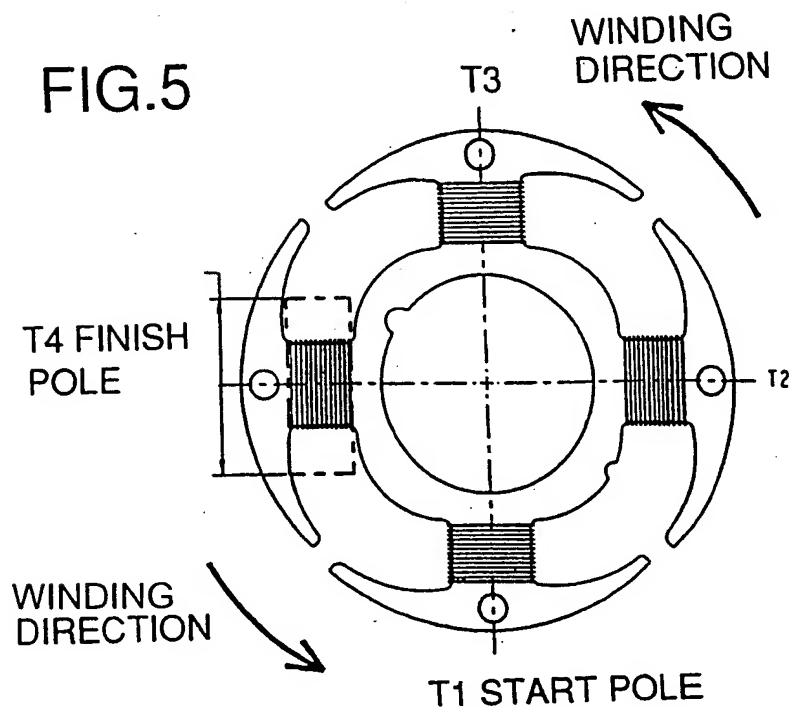
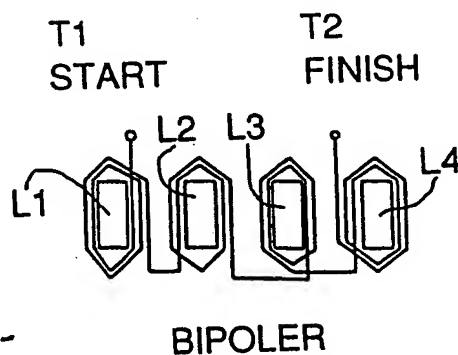


FIG. 6



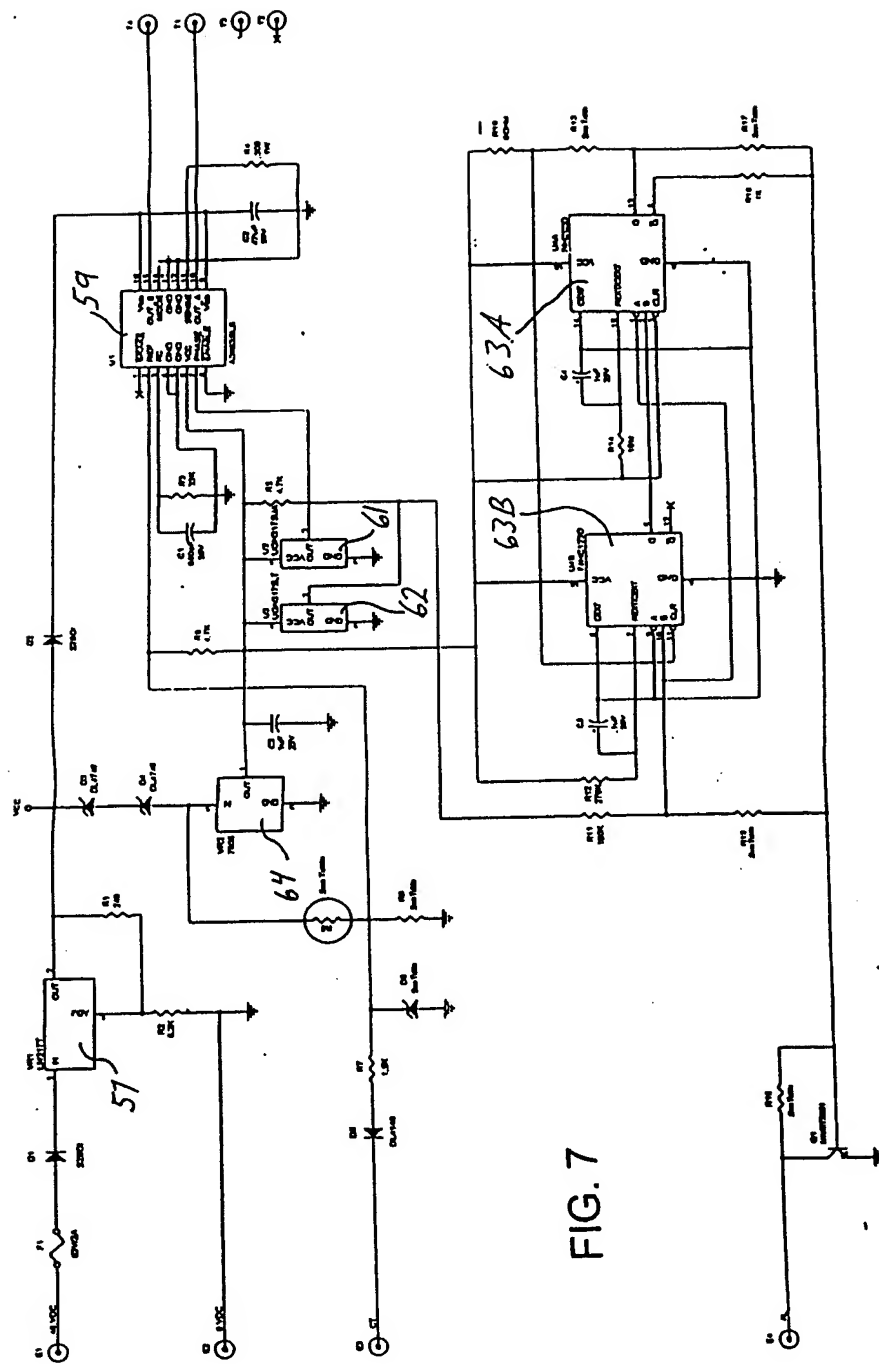


FIG. 7

Title: AN IMPROVED IMPELLER BLADE
Radbury, et al - Experimental

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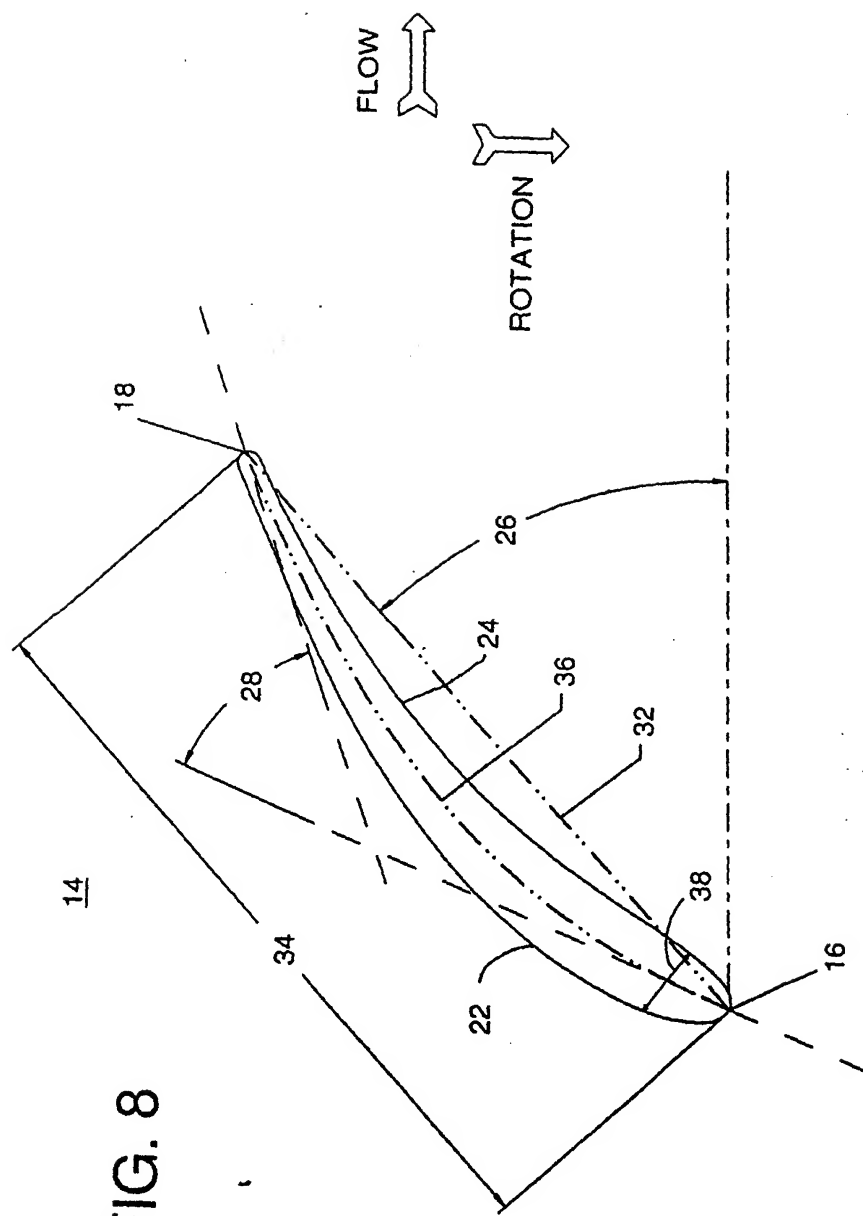


Fig. 8

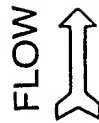


FIG. 9B

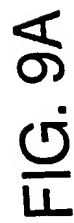


FIG. 9A

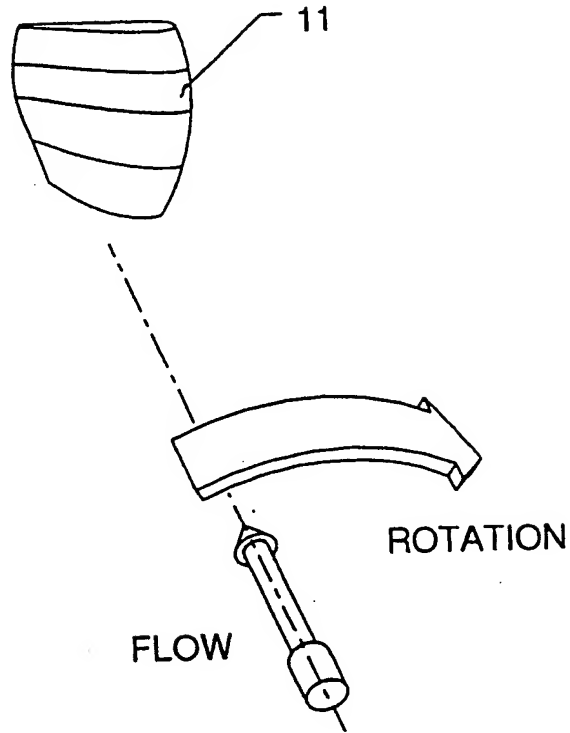


FIG. 10

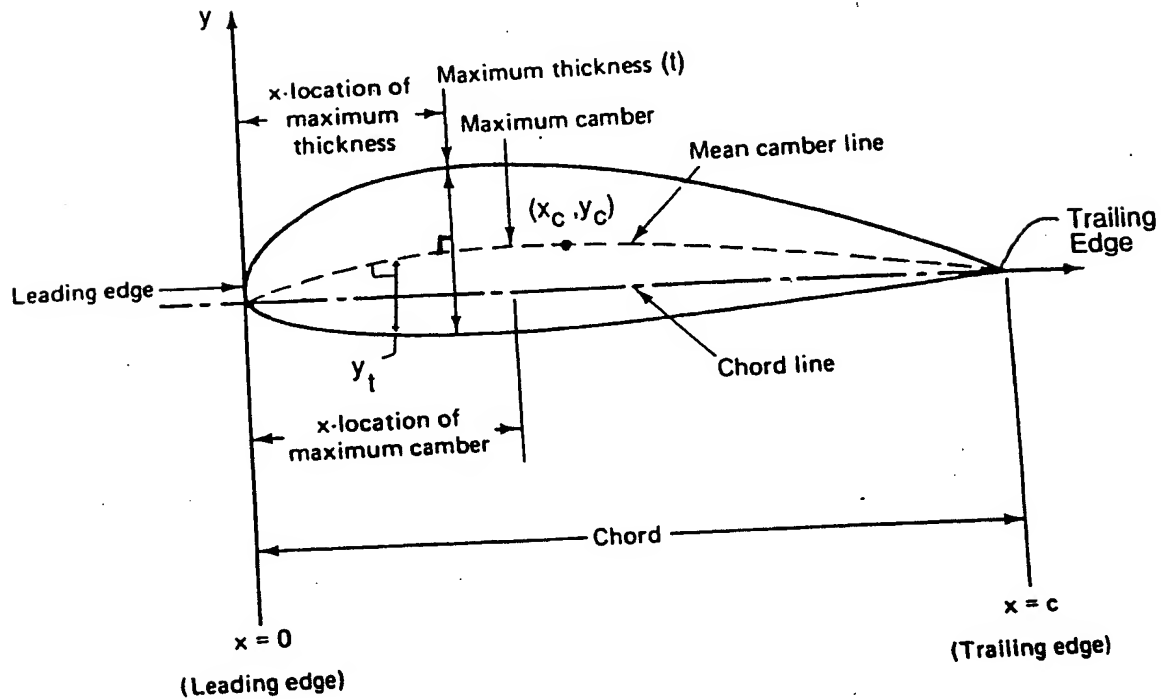


FIG. 11

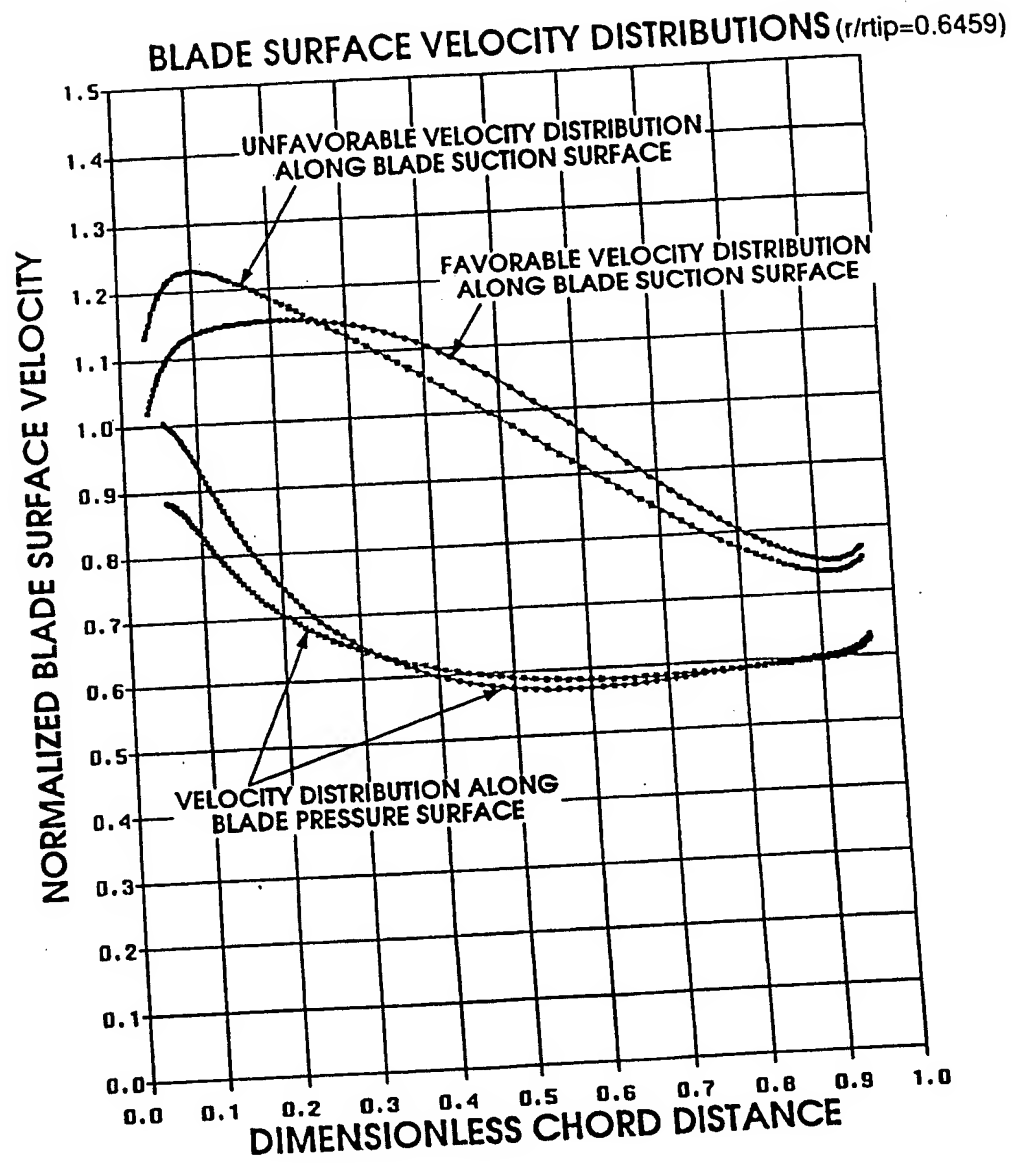


FIG. 12

NORMALIZED BEZIER CONTROL POINTS

k	r/rtip = 0.5009			r/rtip = 0.6459		
	x_k	y_k	t_k	x_k	y_k	t_k
0	0.00	0.00000	3.66090	0.00	0.00000	2.96628
1	1.25	0.58007	5.24729	1.25	0.40469	4.25167
2	2.50	1.16014	6.46759	2.50	0.80938	5.24043
3	5.00	2.32029	8.54210	5.00	1.61876	6.92133
4	7.50	3.48043	12.08097	7.50	2.42814	9.78873
5	10.00	4.64057	12.08097	10.00	3.23751	9.78873
6	15.00	6.96086	12.08097	15.00	4.85627	9.78873
7	20.00	9.28114	12.08097	20.00	6.47503	9.78873
8	30.00	12.34440	12.08097	30.00	9.05043	9.78873
9	40.00	12.34440	10.98270	40.00	9.05043	8.89885
10	50.00	13.37310	7.80992	50.00	9.80463	6.32807
11	60.00	12.34440	7.80992	60.00	9.05043	6.32807
12	70.00	8.22960	5.73541	70.00	6.03362	4.64718
13	80.00	6.86226	3.66090	80.00	4.64103	2.96628
14	90.00	3.48391	3.29481	90.00	2.35621	2.66965
15	95.00	1.79474	3.23379	95.00	1.21381	2.62022
16	97.50	0.95015	3.14227	97.50	0.64260	2.54606
17	98.75	0.52786	3.09651	98.75	0.35700	2.50898
18	100.00	0.00000	3.05075	100.00	0.00000	2.47190

FIG.13A

NORMALIZED BEZIER CONTROL POINTS

k	r/r _{tip} = 0.7909			r/r _{tip} = 0.8954		
	x _k	y _k	t _k	x _k	y _k	t _k
0	0.00	0.00000	2.66901	0.00	0.00000	2.71440
1	1.25	0.28327	3.82559	1.25	0.24026	3.89065
2	2.50	0.56654	4.71526	2.50	0.48052	4.79545
3	5.00	1.13309	6.22770	5.00	0.96103	6.33361
4	7.50	1.69963	8.80774	7.50	1.44155	8.95753
5	10.00	2.26618	8.80774	10.00	1.92207	8.95753
6	15.00	3.39926	8.80774	15.00	2.88310	8.95753
7	20.00	4.53235	8.80774	20.00	3.84414	8.95753
8	30.00	6.54998	8.80774	30.00	5.39486	8.95753
9	40.00	6.54998	8.00704	40.00	5.39486	8.14321
10	50.00	7.09582	5.69389	50.00	5.84443	5.79073
11	60.00	6.54998	5.69389	60.00	5.39486	5.79073
12	70.00	4.36666	4.18145	70.00	3.59657	4.25257
13	80.00	3.09061	2.66901	80.00	2.53886	2.71440
14	90.00	1.56908	2.40211	90.00	1.28896	2.44296
15	95.00	0.80831	2.35763	95.00	0.66401	2.39772
16	97.50	0.42793	2.29090	97.50	0.35153	2.32986
17	98.75	0.23774	2.25754	98.75	0.19530	2.29593
18	100.00	0.00000	2.22418	100.00	0.00000	2.26200

FIG.13B

NORMALIZED BEZIER CONTROL POINTS

k	r/r _{tip} = 1.0000		
	x _k	y _k	t _k
0	0.00	0.00000	3.06144
1	1.25	0.23550	4.38806
2	2.50	0.47100	5.40854
3	5.00	0.94201	7.14336
4	7.50	1.41301	10.10275
5	10.00	1.88402	10.10275
6	15.00	2.82603	10.10275
7	20.00	3.76803	10.10275
8	30.00	4.93440	10.10275
9	40.00	4.93440	9.18432
10	50.00	5.34560	6.53107
11	60.00	4.93440	6.53107
12	70.00	3.28960	4.79626
13	80.00	2.47777	3.06144
14	90.00	1.25795	2.75530
15	95.00	0.64803	2.70427
16	97.50	0.34308	2.62774
17	98.75	0.19060	2.58947
18	100.00	0.00000	2.55120

FIG. 13C

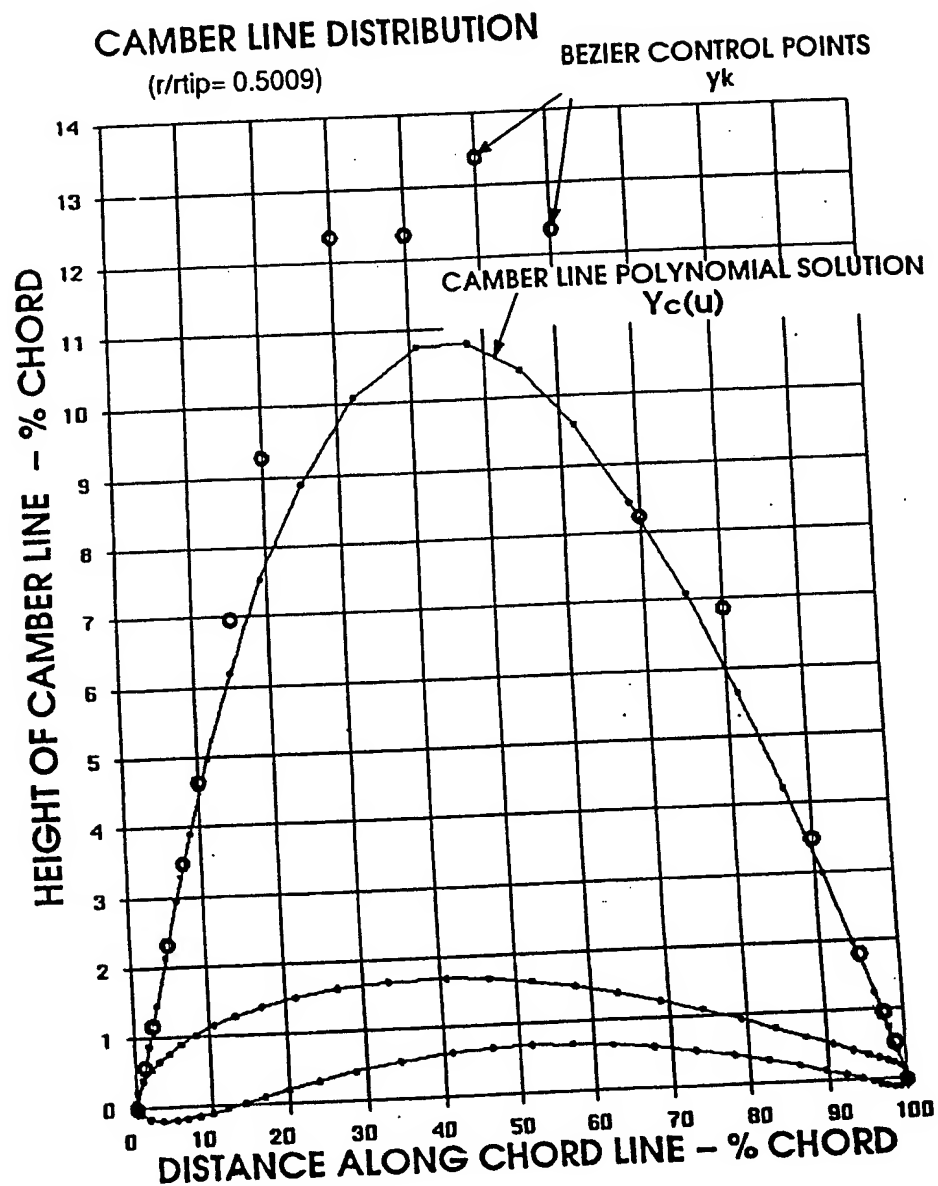


FIG. 14

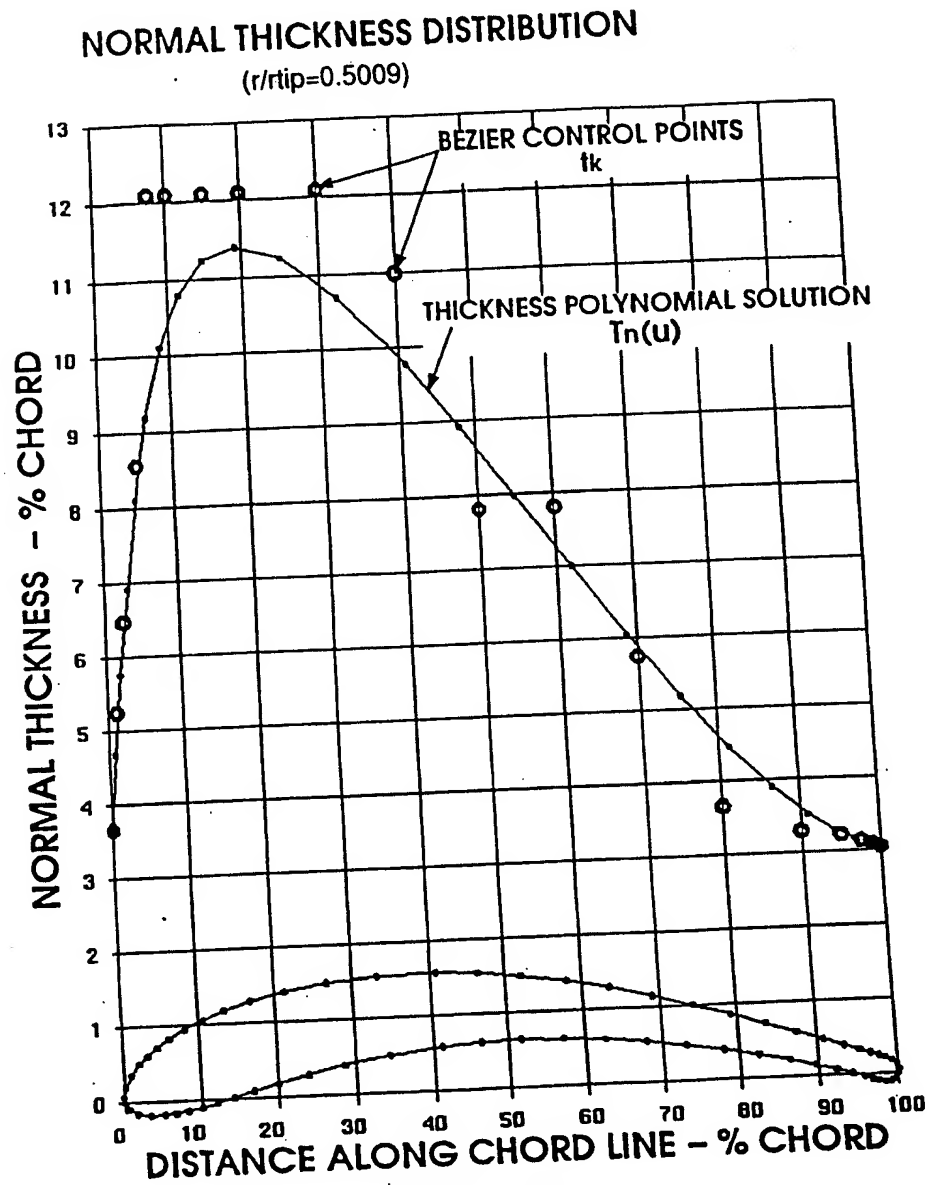


FIG. 15

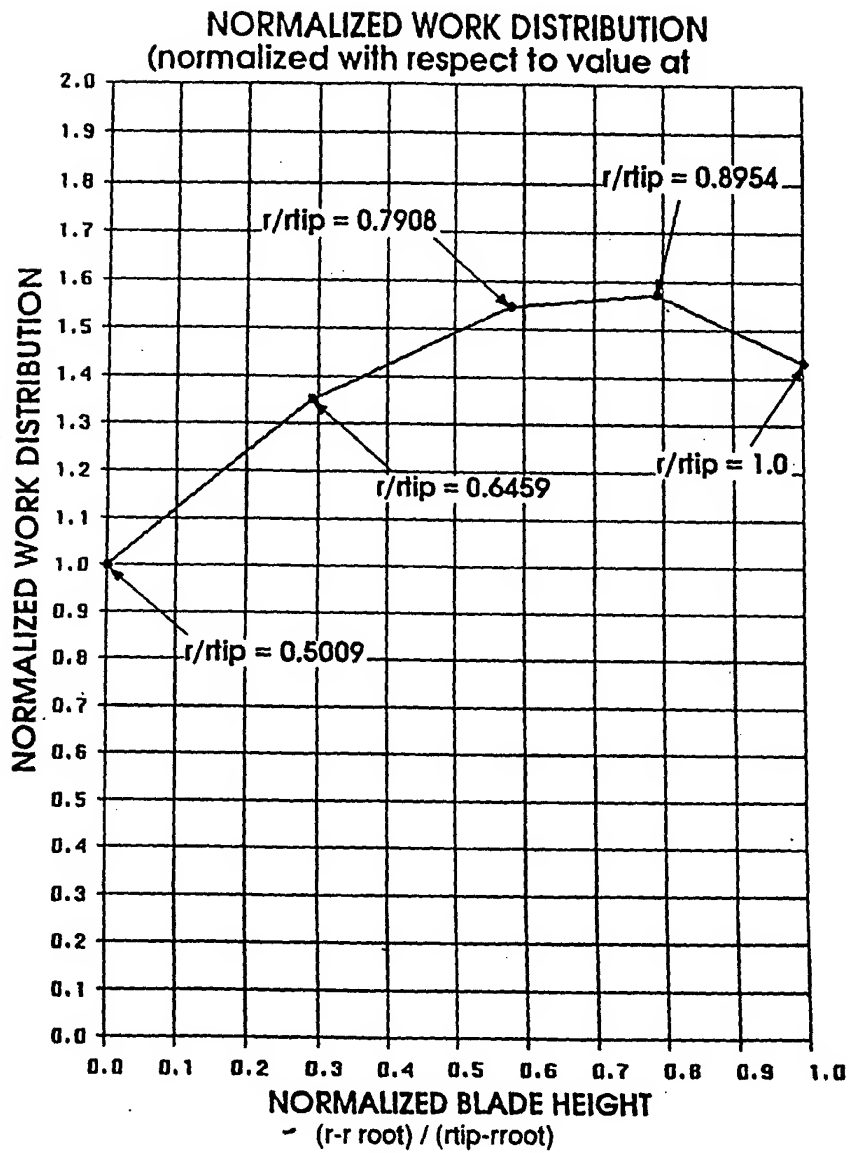


FIG. 16

CAMBER LINE DISTRIBUTION

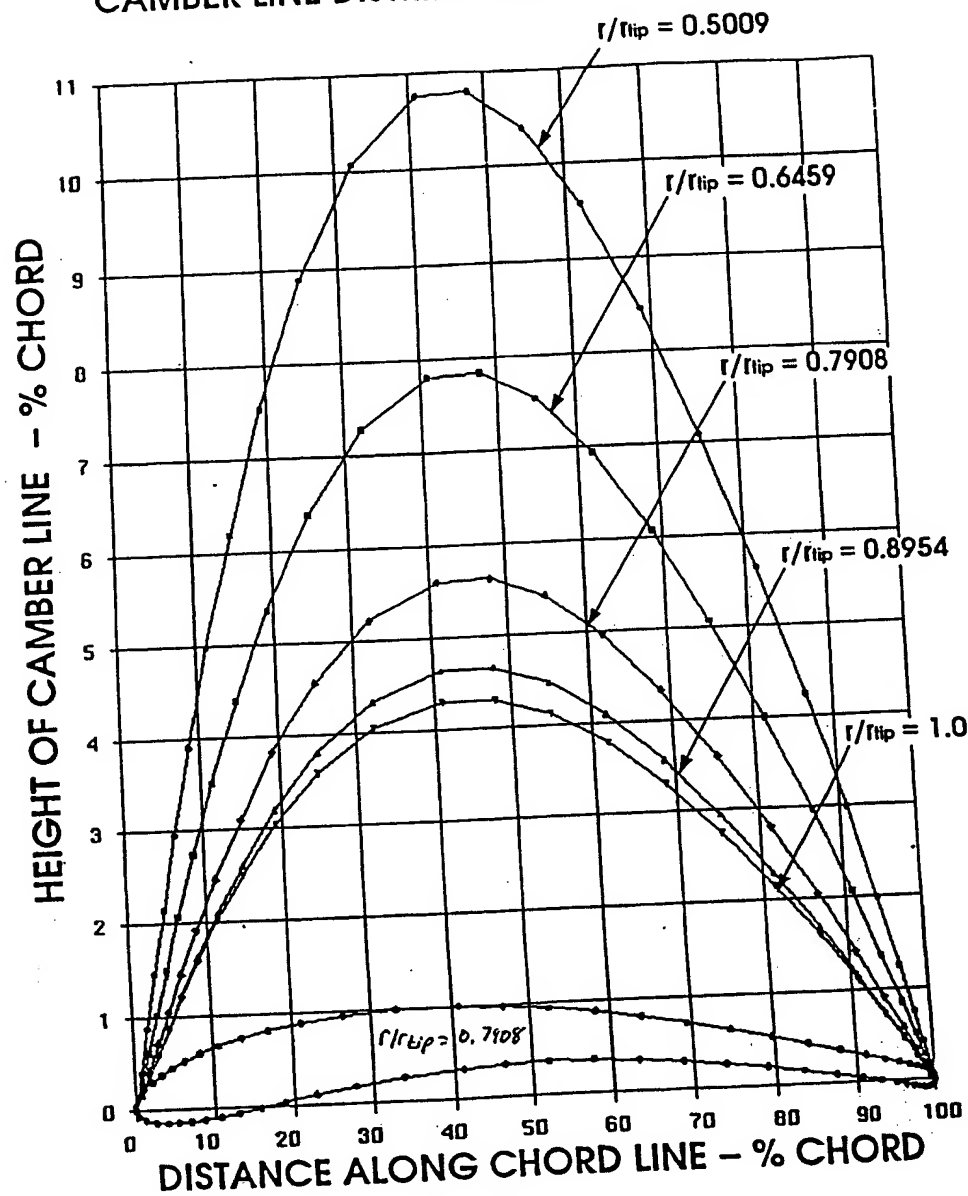


FIG. 17

NORMAL THICKNESS DISTRIBUTION

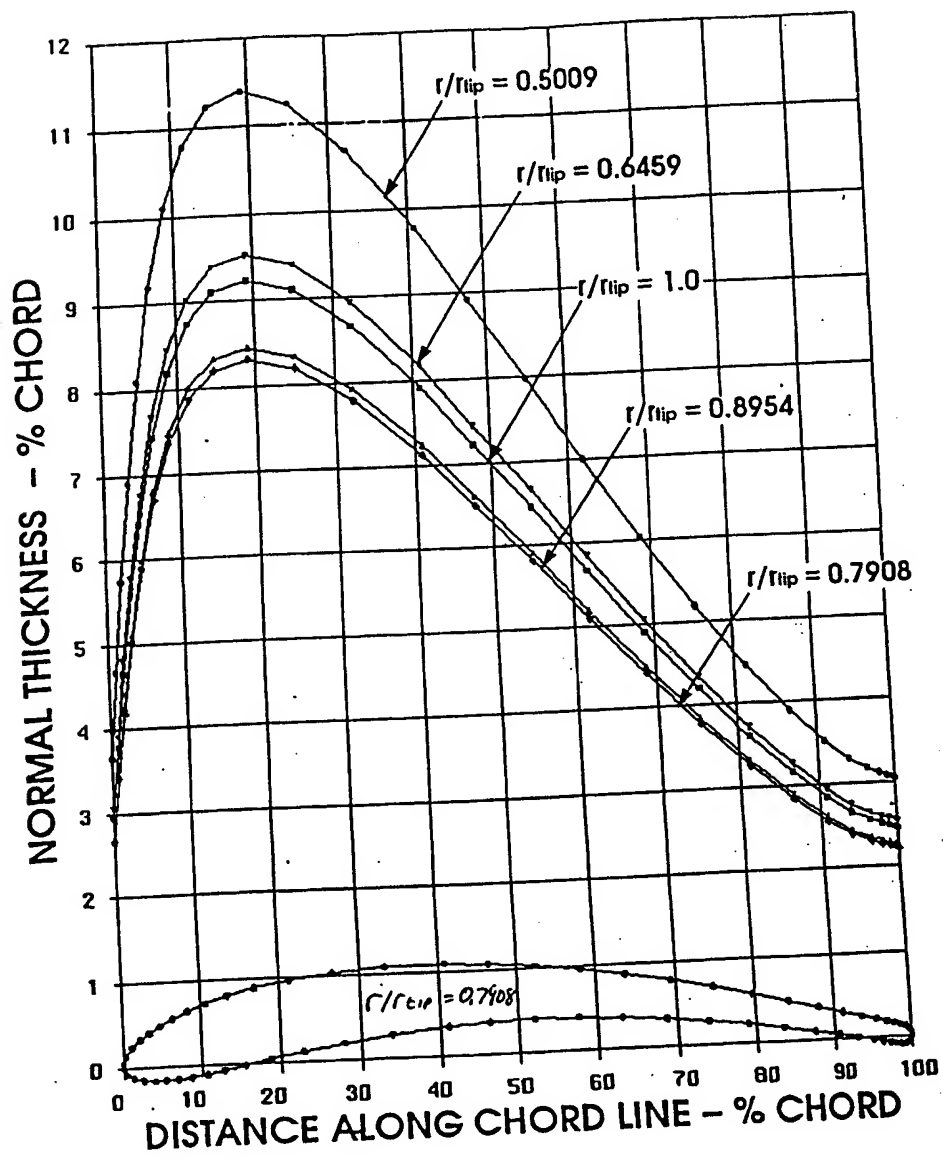


FIG. 18

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NORMALALIZED BLADE PROFILES

- $r/rtip = 0.5009$
- $r/rtip = 0.6459$
- ◇ $r/rtip = 0.7908$
- △ $r/rtip = 0.8954$
- ▽ $r/rtip = 1.0$

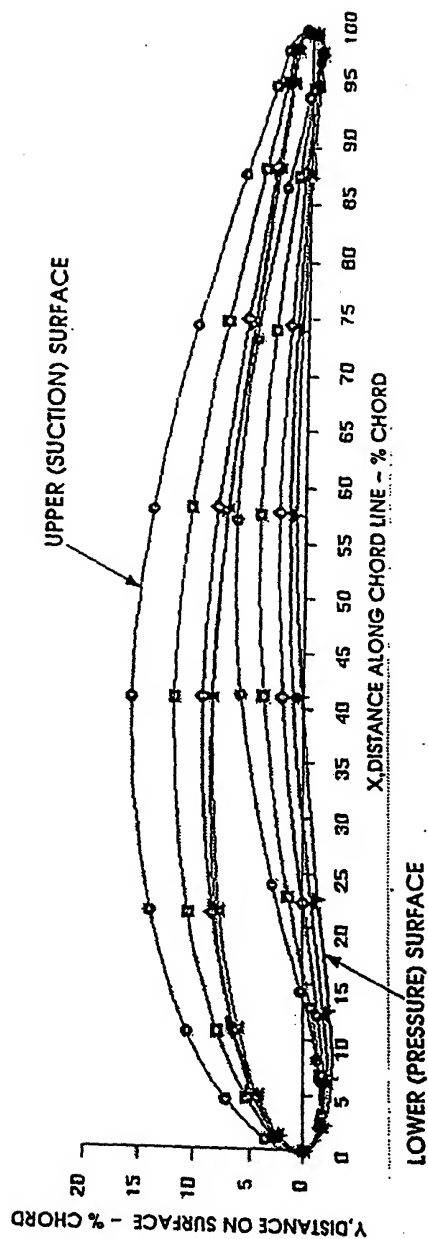


FIG. 19

BLADE DEFINITION	ROOT				TIP
RADIUS (INCHES)	1.4175	1.8278	2.2381	2.5340	2.8300
NORMALIZED RADIUS	0.5009	0.6459	0.7908	0.8954	1.0000
CHORD LENGTH (INCHES)	0.7785	0.9608	1.0678	1.0499	0.9309
NORMALIZED CHORD	0.8363	1.0321	1.1471	1.1278	1.0000
ASPECT RATIO	1.8144	1.4701	1.3228	1.3454	1.5173
SOLIDITY	1.1363	1.0876	0.9871	0.8573	0.6806
STAGGER ANGLE (DEGREES)	41.831	51.330	58.685	62.607	65.653
CAMBER ANGLE (DEGREES)	47.788	33.879	23.537	19.760	19.339
MAXIMUM CAMBER HEIGHT (INCHES)	0.084	0.076	0.060	0.049	0.040
MAXIMUM CAMBER HEIGHT (%CHORD)	10.823	7.863	5.652	4.671	4.320
LOCATION OF MAXIMUM CAMBER (%CHORD)	45.284	45.284	45.284	45.284	45.284
MAXIMUM THICKNESS (INCHES)	0.089	0.089	0.089	0.089	0.089
MAXIMUM THICKNESS (%CHORD)	11.392	9.230	8.305	8.446	9.526
LOCATION OF MAXIMUM THICKNESS (%CHORD)	19.174	19.174	19.174	19.174	19.174
LEADING-EDGE THICKNESS (%CHORD)	3.661	2.966	2.669	2.714	3.062
TRAILING-EDGE THICKNESS (%CHORD)	3.051	2.472	2.224	2.262	2.551
CIRCUMFERENTIAL STACKING DISTANCE (INCHES)	0.0000	0.1335	0.2141	0.2235	0.1806
NORMALIZED CIRCUMFERENTIAL STACKING DISTANCE	0.0000	0.7392	1.1855	1.2375	1.0000
AXIAL STACKING DISTANCE (INCHES)	0.0000	-0.0419	-0.0156	0.0216	0.0800
NORMALIZED AXIAL STACKING DISTANCE	0.0000	-0.5238	-0.1950	0.2700	1.0000

FIG. 20

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 0.5009$

#	XUPPER/C	YUPPER/C	XLOWER/C	YLOWER/C
1	0.00000	0.00000	0.00000	0.00000
2	-0.00164	0.00733	0.00538	-0.00793
3	0.00112	0.02029	0.01684	-0.01404
4	0.00932	0.03584	0.03360	-0.01692
5	0.02109	0.05019	0.05180	-0.01640
6	0.03931	0.06661	0.07545	-0.01370
7	0.06421	0.08411	0.10315	-0.00822
8	0.09831	0.10227	0.13646	0.00050
9	0.14433	0.12045	0.17809	0.01242
10	0.20666	0.13769	0.23280	0.02722
11	0.29321	0.15170	0.30878	0.04402
12	0.40785	0.15637	0.41136	0.05873
13	0.48494	0.15187	0.48213	0.06348
14	0.56303	0.14173	0.55559	0.06390
15	0.64006	0.12684	0.62986	0.05993
16	0.71399	0.10868	0.70267	0.05211
17	0.78256	0.08915	0.77127	0.04156
18	0.84321	0.07028	0.83245	0.02976
19	0.89333	0.05387	0.88311	0.01831
20	0.93118	0.04111	0.92126	0.00858
21	0.95695	0.03225	0.94706	0.00135
22	0.97313	0.02657	0.96313	-0.00349
23	0.98367	0.02280	0.97349	-0.00677
24	0.99251	0.01884	0.98231	-0.00908
25	0.99912	0.01295	0.99065	-0.00883
26	1.00154	0.00617	0.99676	-0.00546
27	1.00000	0.00000	1.00000	0.00000

FIG. 21A

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 0.6459$

#	XUPPER/C	YUPPER/C	XLOWER/C	YLOWER/C
1	0.00000	0.00000	0.00000	0.00000
2	-0.00057	0.00593	0.00353	-0.00679
3	0.00305	0.01558	0.01204	-0.01235
4	0.01137	0.02663	0.02502	-0.01565
5	0.02239	0.03650	0.03950	-0.01647
6	0.04094	0.04910	0.06167	-0.01599
7	0.06557	0.06248	0.08862	-0.01328
8	0.09882	0.07623	0.12200	-0.00765
9	0.14379	0.08999	0.16473	0.00103
10	0.20537	0.10319	0.22185	0.01256
11	0.29210	0.11407	0.30204	0.02621
12	0.40847	0.11762	0.41074	0.03848
13	0.48605	0.11394	0.48434	0.04248
14	0.56498	0.10580	0.56036	0.04300
15	0.64310	0.09394	0.63677	0.04002
16	0.71816	0.07960	0.71120	0.03406
17	0.78765	0.06441	0.78079	0.02610
18	0.84872	0.05007	0.84229	0.01738
19	0.89859	0.03800	0.89258	0.00916
20	0.93558	0.02899	0.92982	0.00240
21	0.96021	0.02299	0.95452	-0.00245
22	0.97534	0.01928	0.96961	-0.00560
23	0.98497	0.01688	0.97912	-0.00767
24	0.99235	0.01445	0.98650	-0.00886
25	0.99813	0.01031	0.99327	-0.00797
26	1.00065	0.00511	0.99791	-0.00470
27	1.00000	0.00000	1.00000	0.00000

FIG. 21B

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 0.7908$

#	XUPPER/C	YUPPER/C	XLOWER/C	YLOWER/C
1	0.00000	0.00000	0.00000	0.00000
2	-0.00002	0.00532	0.00261	-0.00633
3	0.00405	0.01350	0.00976	-0.01180
4	0.01246	0.02246	0.02106	-0.01554
5	0.02316	0.03013	0.03388	-0.01720
6	0.04207	0.04036	0.05523	-0.01835
7	0.06677	0.05104	0.08164	-0.01775
8	0.09972	0.06171	0.11492	-0.01464
9	0.14420	0.07212	0.15811	-0.00877
10	0.20533	0.08191	0.21639	-0.00027
11	0.29193	0.08973	0.29865	0.01036
12	0.40884	0.09169	0.41037	0.02047
13	0.48655	0.08831	0.48539	0.02408
14	0.56581	0.08151	0.56268	0.02509
15	0.64440	0.07187	0.64012	0.02345
16	0.71997	0.06045	0.71531	0.01955
17	0.78988	0.04857	0.78535	0.01415
18	0.85113	0.03762	0.84695	0.00821
19	0.90087	0.02868	0.89702	0.00265
20	0.93743	0.02222	0.93380	-0.00185
21	0.96150	0.01808	0.95797	-0.00502
22	0.97614	0.01559	0.97261	-0.00705
23	0.98535	0.01402	0.98176	-0.00836
24	0.99210	0.01236	0.98851	-0.00894
25	0.99754	0.00909	0.99456	-0.00766
26	1.00018	0.00463	0.99850	-0.00438
27	1.00000	0.00000	1.00000	0.00000

FIG. 21C

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 0.8954$

#	XUPPER/C	YUPPER/C	XLOWER/C	YLOWER/C
1	0.00000	0.00000	0.00000	0.00000
2	0.00015	0.00543	0.00245	-0.00654
3	0.00456	0.01368	0.00954	-0.01240
4	0.01340	0.02259	0.02092	-0.01665
5	0.02452	0.03007	0.03391	-0.01884
6	0.04367	0.03972	0.05514	-0.02078
7	0.06861	0.04958	0.08145	-0.02110
8	0.10173	0.05913	0.11469	-0.01911
9	0.14620	0.06809	0.15790	-0.01461
10	0.20706	0.07612	0.21624	-0.00770
11	0.29306	0.08204	0.29855	0.00125
12	0.40901	0.08262	0.41020	0.01019
13	0.48630	0.07908	0.48527	0.01374
14	0.56519	0.07269	0.56254	0.01525
15	0.64350	0.06399	0.63990	0.01463
16	0.71889	0.05388	0.71497	0.01213
17	0.78871	0.04349	0.78489	0.00831
18	0.84996	0.03399	0.84643	0.00391
19	0.89976	0.02628	0.89652	-0.00033
20	0.93644	0.02076	0.93340	-0.00384
21	0.96066	0.01724	0.95769	-0.00637
22	0.97541	0.01513	0.97245	-0.00799
23	0.98470	0.01380	0.98169	-0.00906
24	0.99160	0.01232	0.98859	-0.00945
25	0.99722	0.00916	0.99472	-0.00796
26	1.00003	0.00471	0.99862	-0.00450
27	1.00000	0.00000	1.00000	0.00000

FIG. 21D

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 1.0000$

#	XUPPER/C	YUPPER/C	XLOWER/C	YLOWER/C
1	0.00000	0.00000	0.00000	0.00000
2	0.00018	0.00621	0.00274	-0.00746
3	0.00514	0.01586	0.01079	-0.01447
4	0.01507	0.02637	0.02371	-0.01981
5	0.02757	0.03517	0.03844	-0.02274
6	0.04710	0.04531	0.06005	-0.02523
7	0.07255	0.05535	0.08658	-0.02599
8	0.10619	0.06474	0.11987	-0.02446
9	0.15092	0.07313	0.16285	-0.02056
10	0.21140	0.08015	0.22046	-0.01444
11	0.29594	0.08465	0.30118	-0.00635
12	0.40909	0.08385	0.41012	0.00215
13	0.48526	0.07979	0.48413	0.00598
14	0.56302	0.07320	0.56031	0.00815
15	0.64027	0.06461	0.63663	0.00852
16	0.71478	0.05481	0.71079	0.00722
17	0.78401	0.04481	0.78008	0.00461
18	0.84506	0.03563	0.84138	0.00125
19	0.89512	0.02811	0.89170	-0.00226
20	0.93243	0.02263	0.92917	-0.00536
21	0.95741	0.01907	0.95420	-0.00771
22	0.97283	0.01690	0.96961	-0.00928
23	0.98268	0.01552	0.97940	-0.01035
24	0.99047	0.01387	0.98718	-0.01073
25	0.99682	0.01033	0.99408	-0.00901
26	1.00001	0.00531	0.99847	-0.00508
27	1.00000	0.00000	1.00000	0.00000

FIG. 21E